Characterization of short gate length AlGaN/GaN HEMTs

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Significant progress has been made in the last view years in the development of GaN-based transistors. Especially GaN-based high electron mobility transistors (HEMTs) have demonstrated excellent high frequency performance at high power. We will report on our progress on the fabrication of AlGaN/GaN HEMTs with extremely short gate lengths down to 60 nm to investigate DC- and high frequency behavior as well as short-channel effects.

Our samples were grown by low pressure MOVPE on (0001) sapphire substrate and our structures typically consist, from bottom to top, of an AlN buffer layer, a 1 to 2 μm thick undoped GaN layer followed by a 30 to 40 nm thick undoped AlGaN layer. To get extremely short gate lengths we have developed a 3-layer e-beam-resist technique, consisting of two PMMA (Poly-Methyl-Metacrylat; 1%, 9%) layers and one copolymer layer, which is a high-sensitive electron beam resist to form the top of the T-gate. The change of the resist layer thickness, the metallization thickness and the e-beam dose allows a very flexible T-gate design, which results in T-gates with different sizes (Fig. 1).

A typical feature of short-channel effects is the loss of saturation in the output characteristics. The transconductance of the devices with gate lengths below 200 nm seems to become smaller with decreasing gate length probably due the gate-fringing effect (Fig. 2). We have also investigated the breakdown behavior of this devices. Fig. 3 shows that our short channel devices can operate at drain voltages higher than one order of magnitude compared to HEMTs based on AlGaAs/GaAs even at gate length down to 70 nm. Another deleterious short-channel effect is a strong dependency of the threshold voltage on the gate length, which could be also explained by gate-fringing (Fig.4). Nevertheless the short-channel devices show quite stable transistor datas and even for non-optimized transistor material cut-off frequencies up to 43 GHz and maximum oscillation frequencies larger than 100 GHz. The maximum extrinsic transconductance reaches up to 155 mS/mm. A significant improvement is expected for gate length below 50 nm where ballistic transport should be possible.

Furthermore depending on varying recess depth analysis of gate fringing will be presented.

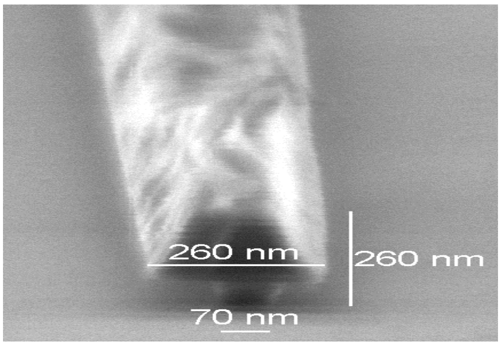

Fig.1. SEM picture of 70 nm T-gate

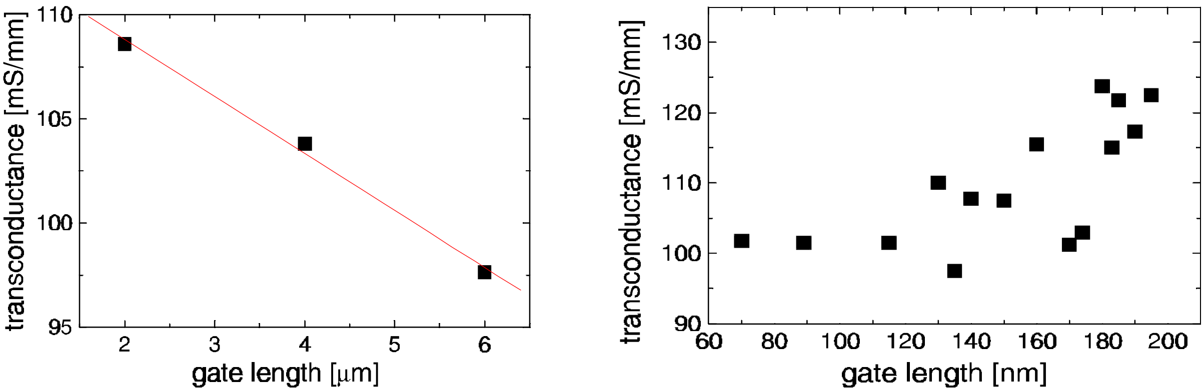

Fig. 2. Transconductance at U_D=7 V dependent on the gate length

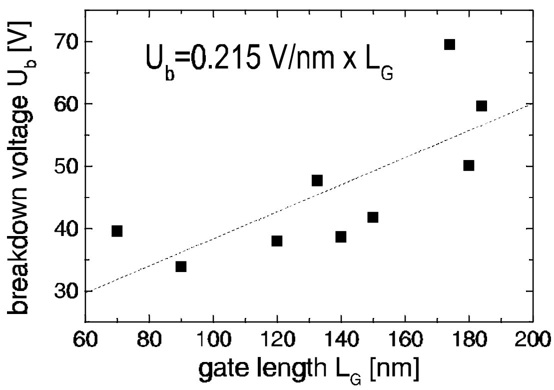

Fig. 3. Breakdown voltage dependent on the gate length

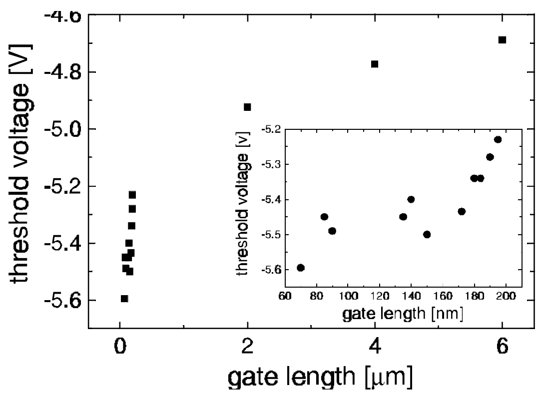

Fig. 4. Threshold voltage dependent on the gate length